

# **Appendix D**

## **Anomaly, Failure and Mishap Reporting**



## D.1 Introduction

In accordance with NSTS/ISS 13830, Payload Safety Review and Data Submittal Requirements, the AMS-02 Project has prepared this summary of anomalies, failures and Mishaps associated with flight and qualification hardware. This summary does not consider what are considered normal manufacturing deviations and discrepancies as failures or anomalies unless they rise to a clear safety impact status. All such manufacturing discrepancies associated with the AMS-02 Integration Hardware built and procured through Johnson Space Center are documented in the JSC QARC system.

Similar discrepancies from international suppliers of hardware are reported along with anomalies and failures to the AMS-02 Project Office, but only the anomalies and failures are recorded.

## D.2 Significant Events

No.	ID	Title	Status
1.	AMS-02-A01	HV Board Interconnect Failure.	Closed
2.	AMS-02-A02	Uninterruptible Power Supply FET Cracked	Closed
3.	AMS-02-A03	Improper Torquing of ECAL Fasteners	Closed
4.	AMS-02-A04	Anomaly of Thermal Conductor of AMS Internal Tracker	Closed



**1. AMS-02-A01 – HV Board Interconnect Failure.**

**Description of Event:** During thermal cycle testing high voltage electronics associated with the ECAL, RICH and TOF High Voltage power supplies experienced channel failures. Subsequent investigation indicated that during thermal cycling testing the straight forked pins that interconnect the 16 mini-boards of the linear regulator were shown to have experienced thermally induced stresses that broke the solder connection. These thermal stresses were induced between the solder joint and the resin of the boards.

**Corrective Action:** The straight forked pins interconnecting between the 16 mini-boards were replaced in a test configuration and qualification unit 2 with reshaped pins that provide a strain relief function that the straight pins could not provide. A test board has been constructed and tested at CAEN as follows: 1) burn-in for 8 hours with a temperature of 70°C ; 2) thermo-vacuum test with pressure of 0.1mBar, verifying the absence of discharges ; 3) thermal cycles (10 cycles in total between -30 °C and +70 °C, with a ramp-up rate of 4 °C /min, down-ramp rate of 2 °C /min and time of permanence at each temperature of 1 hour). At the end of each cycle, all the channels were inspected. No problem was observed.

**Safety Impact:** The loss of the high voltage sources within the RICH, ECAL and TOF would have had a significant impact on the science objectives of the AMS-02, but no significant impact to safety. Flight bricks will be fully potted, and the separation of the of the solder joint would not have created a sparking/ignition source concern or coronal discharge source. At worst this failure may have manifested as an increase in EMI noise because of intermittent contact and operation. This failure/anomaly has been classified as NON SAFETY CRITICAL.

**Status:** Closed

**SUPPORTING DOCUMENTATION: (follows)**



AMS-note

2005-09-02

## Modifications of ECAL, RICH and TOF High Voltage Power Supply QM design

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5 september 2005

This note describes the modifications applied to the QM2 version of the High Voltage Power Supply (*brick*), to be used by ECAL, RICH and TOF subdetectors. The modifications became necessities in front of failures registered during thermal tests performed both by the supplying company (CAEN - Italy) and by the INFN-Pisa, responsible of the ECAL subdetector construction.

In this note we report (1) how the QM1 was constructed, (2) the failures observed, (3) the new design of the QM2 and the status of the tests necessary to validate the new design.

### 1 – Construction of QM1

The *AMS brick* is described in AMS note 2005-09-01 .

In short, it is a modular structure providing the High Voltage (from 0.5kV up to 2.5kV) for the readout Photomultipliers (PMTs) used by the three subdetectors.

Three main components characterize the brick:

1. *Controller Board* communicating with the AMS electronics through the LeCroy slow control protocol and providing the low voltages to the DC/DC converters ;
2. *DC/DC Converter* generating the HV (up to 2.5 kV) from the 28V supplied by the International Space Station ;
3. *Linear Regulators* regulating the output voltage to the PMTs with a precision of  $\Delta V/1024$ , where  $\Delta V$  is the operative range of the readout .

The number of DC/DC convertors and Linear Regulators is different for the three subdetectors, as reported in AMS note 2005-09-01 .

The *Linear Regulator* consists of a main board, with approximate dimensions  $5 \times 20 \text{ cm}^2$ , on which 16 *mini boards*, actually performing the HV regulation for each channel, are soldered in the vertical position (see picture 1). The soldering is done through *fork pins* which are shown in figure 2.

In the QM1, the *fork pins* had a straight shape, so that no strain relief was foreseen.

After soldering the 16 mini boards, all the Linear Regulator is filled with resin, both to limit discharges and to mechanically protect the electrical components.

### 2 – Tests done on QM1



The different parts of two *brick* for ECAL and TOF subdetectors were mounted, and tested at CAEN and at INFN Pisa (ECAL *brick*, only). After thermal cycles between -20°C and +70°C (and after some trips from Pisa to CERN!) the two HV modules showed some malfunctioning channels.

To investigate the problem, the TOF *brick* was dismantled and the Linear Regulators were carefully inspected. As a result, some of the SMD soldering of the straight pins were found to be broken, as shown in figure 3. According to CAEN, the failures were due to different thermal coefficient between resin and soldering material, generating a stress able to cause the connection rupture.

To solve the problem, CAEN suggested to modify the pin shape.

### 3 – Modifications on the design and tests on QM2

The CAEN proposal for the new pin shape is shown in figures 4 and 5. With this new shape, the pins should act as a strain relief and decrease the stress generated on the soldering pads by the thermal expansion.

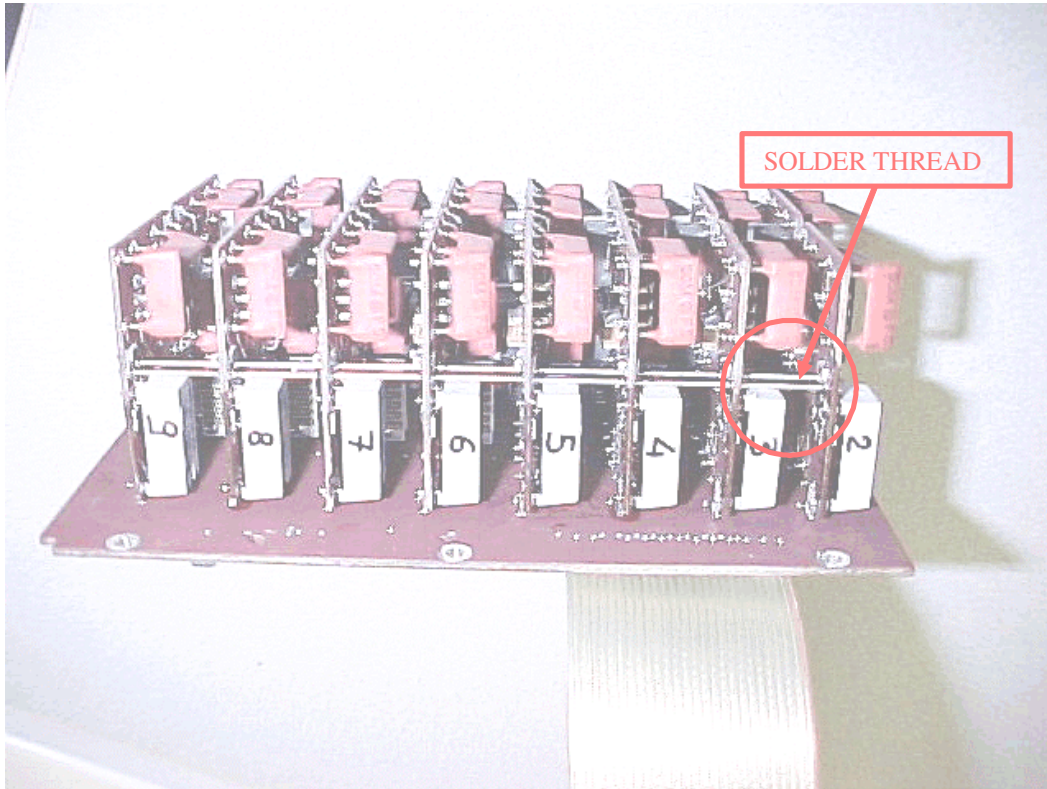
A test board has been constructed and tested at CAEN as follows:

1. burn-in for 8 hours with a temperature of 70°C ;
2. thermo-vacuum test with pressure of 0.1mBar, verifying the absence of discharges ;
3. thermal cycles (10 cycles in total between -30°C and +70°C, with a ramp-up rate of 4°C/min, down-ramp rate of 2°C/min and time of permanence at each temperature of 1 hour).

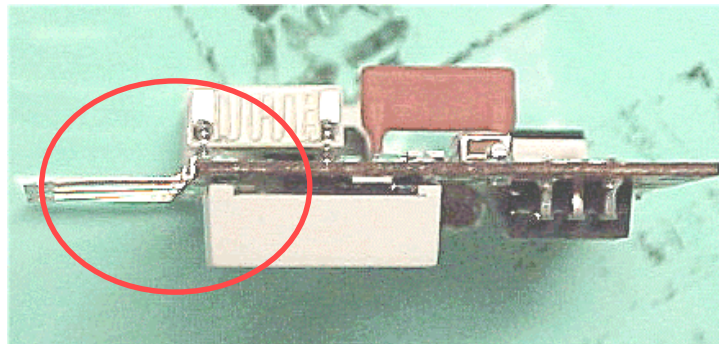
At the end of each cycle, all the channels were inspected. No problem was observed.

After these tests, a QM2 *brick* module, with 5 *Linear Regulator* boards and 1 *DC/DC converter*, was built to be tested by the RICH and ECAL groups. The tests will be performed in September 2005. Results will be reported in a following note.





Picture 1 – side view of TOF Linear Regulator.



Picture 2 – View of the single regulator mini board with closeup of the straight pins used for the soldering of this component with the Linear Regulator main board.



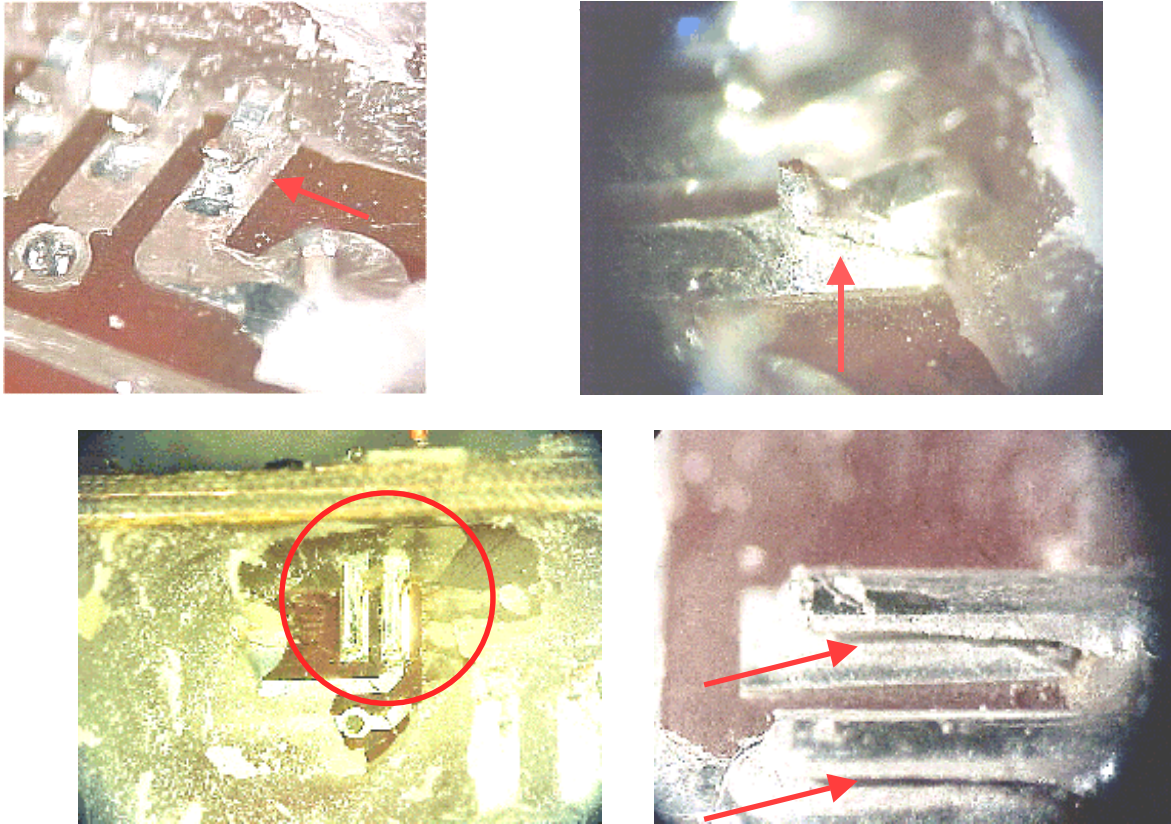


Figure 3 – Pictures of the pads where the *fork pins* were soldered.

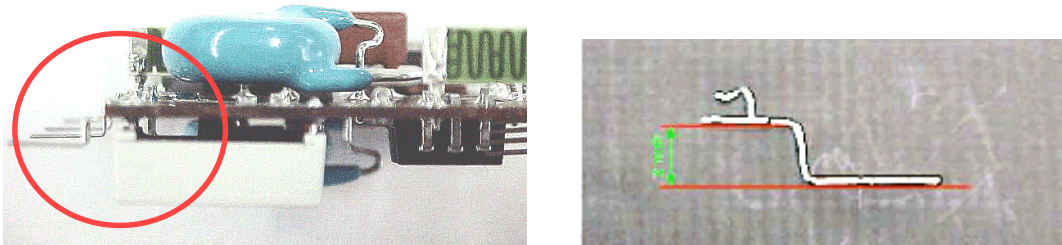


Figure 1 – New mini board with preformed pins(left). New shape of *fork pins* (right).



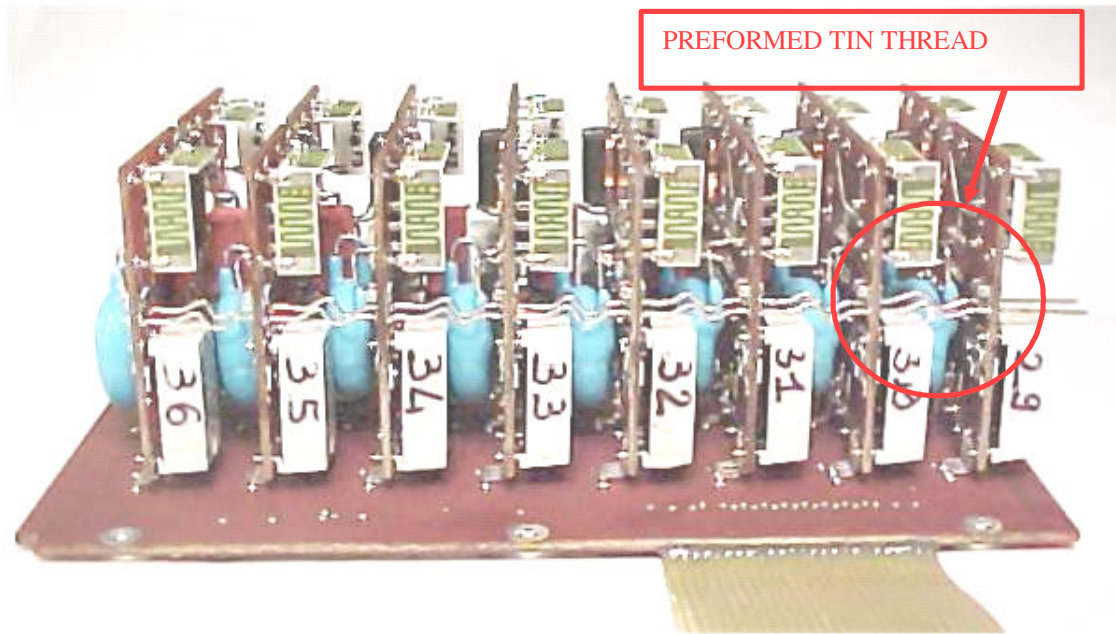


Figure 5

– QM2 test board. Also the interconnection thread has been preformed.

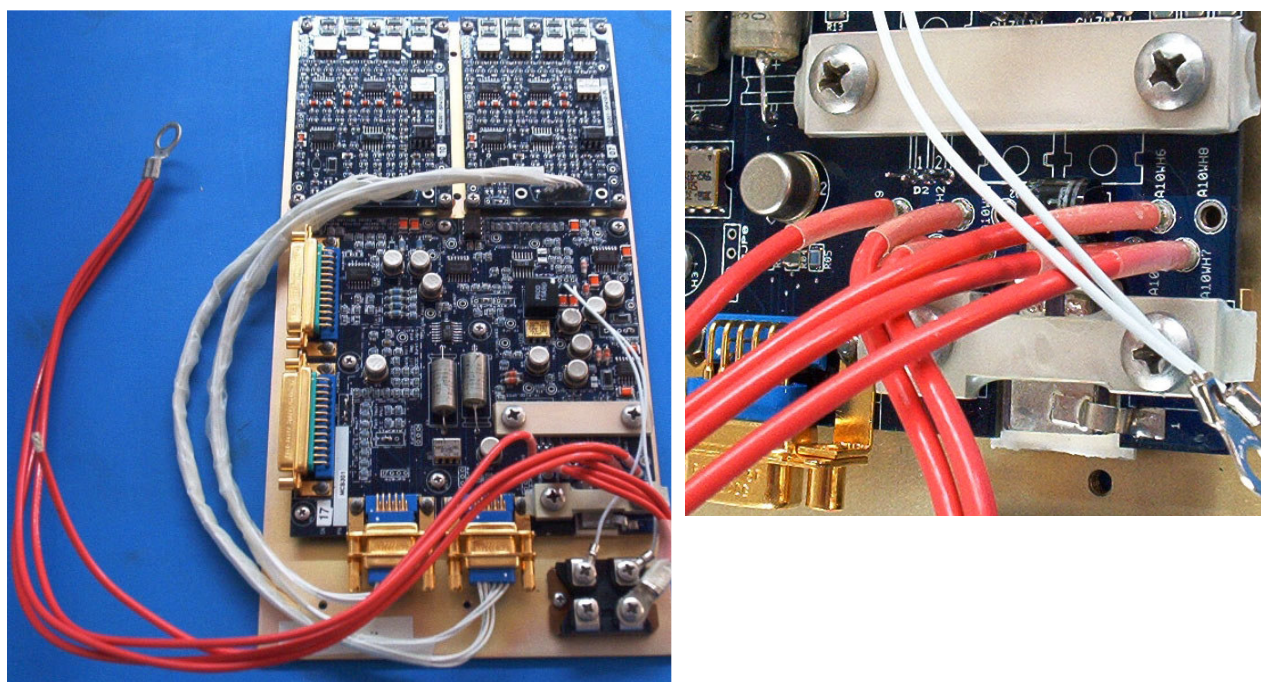


## 2. AMS-02-A02 – Uninterruptible Power Supply FET Cracked

**Description of Event:** During the final system testing of the full electronics assembly at Eaves Devices, the last board (5<sup>th</sup> out of 5) tested failed the current interruption test (support 77A for 360ms to 1500ms). Upon examination of the board, it was discovered that the FET was cracked under the compression bar holding it in contact with the heat sink. These cracks apparently shorted the device, causing it to fail under high current. As shown in the attached pictures, the FET (located in the front right of the AMS BMS picture, near all the big red wires) has a compression bar over the top of it, holding it in contact with two layers of SIL-PAD and an aluminum heat sink. Per Eaves Devices assembly procedures, the screws on this compression bar are only torqued to 6 in-lbs.

Further examination of the other 4 boards revealed that the FETs in those boards showed signs of cracking, but had not failed any testing.

The FET on the failed board was removed and an industrial version of the FET was put in place to test the rest of the circuitry and confirm that no other damage had been done. All circuits performed normally.



**Corrective Action:** Compression bar was eliminated from the design and a thermally conductive adhesive was used. Material usage was approved by JSC Materials. Thermal performance and board function were retested and found acceptable.

**Safety Impact:** The FET was functioning in a critical battery protection function, protecting the system against external shorts. Corrective actions were essential in maintaining system safety.

**Status:** Closed



### 3. AMS-02-A03 – Improper Torquing of ECAL Fasteners

**Description of Event:** The torques specified and used in the assembly of the ECAL were for a dry installed fastener interface. Dry install torques are higher than lubricated install torques due to the need to overcome the higher coefficient of friction of bare metal to metal contact. All of the structural inserts and nuts used to assembly the ECAL have a dry film lubricant coating that acts to reduce the friction of the fasteners during installation. Margins of safety for the ECAL fasteners were recalculated using the torques called out in the assembly process with a lubricated interface. The analysis results showed that possible yielding had occurred during the installation of the fasteners.

**Corrective Action:** All of the structural fasteners that showed negative margins of safety have been either be removed, inspected and reinstalled or be replaced with new fastener and preloaded to torques specified according the latest analysis results. Drawings/installation instructions indicating the dry insertion torques have been corrected to reflect correct lubricated values. Structural margins have been confirmed to be positive after rework.

**Safety Impact:** The ECAL bolts improperly installed failed to have sufficient structural margin, making this assembly error SAFETY CRITICAL. Corrective actions were witnessed to confirm full compliance and to assure positive margins were regained.

**Status:** Closed



#### **4. AMS-02-A04 – Anomaly of Thermal Conductor of AMS Internal Tracker**

**Description of Event:** During assembly copper braids used as thermal conductors were observed as having broken wire elements after undergoing in situ compression (a required process). None were found to be loose, but separated.

**Corrective Action:** Heat shrink tubing implemented over braids to contain any possible fragments. Fragment generation unlikely as copper conductors were only broken on one side and still retained on the other. Additional containment within tracker is provided by mesh filters at light tight vents.

**Safety Impact:** There was a potential of generating small debris that was electrically conductive. While this is not a concern beyond mission success for the Tracker, the loose wire fragments co-orbiting with the ISS was undesirable. The safety assessment considered this Safety Critical, and design features in place and corrective procedures were deemed adequate to protect against this remote hazard.

**Status:** Closed

**SUPPORTING DOCUMENTATION: (follows)**





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## Report on Anomalies and Modifications of Thermal Connectors during Assembly of AMS Internal Tracker

Prof. Divic RAPIN

**Date:** September 1, 2006

**Re:** Thermal connectors (Copper braids) connecting to each other the thermal bars of planes 2, 3 and 4 of the tracker.

**Location:** University of Geneva clean rooms (veranda).

**Observations:** Some threads of the Copper braids used as thermal connectors between inner planes were found to be damaged during the assembly (*See Appendix A*). The damaged threads are broken on one side only and none was found to be loose. The loss of thermal conductivity is negligible.

**Reporting:** AMS TIM July 2006 at CERN

**Actions taken:** Study of a containment procedure of the Copper braids using space qualified heat shrink tubing (*See Appendix B*). This tubing must be installed *in situ* after vacuum cleaning of the braids with examination of the filter. The heating should not damage the electronics.

**Results:** Application of this procedure to the 192 thermal connectors of the inner tracker during its assembly. (*See Appendix C*)

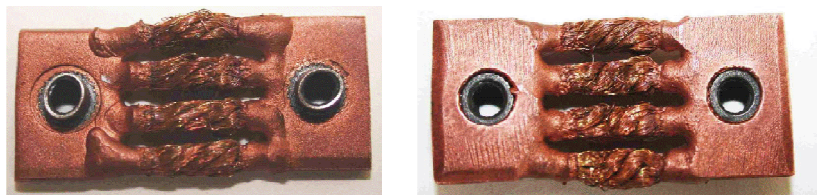
**Safety assessment:**

- No damaged thread was found to be loose.
- Damaged threads are broken on a single location, reducing the stress.
- Two containment barriers exist:
  - 1: heat shrink tubing around the braids (new).
  - 2: mesh in the light tight venting apertures containing material in the inner tracker.

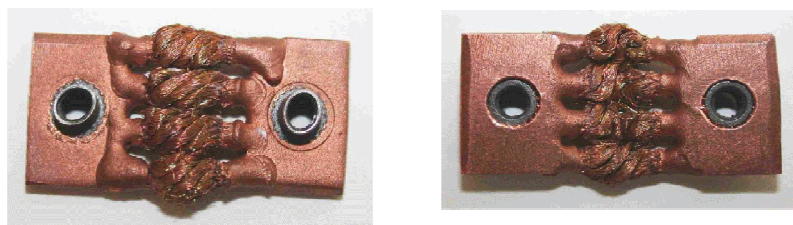


### Appendix A: Thermal connector compression, damages

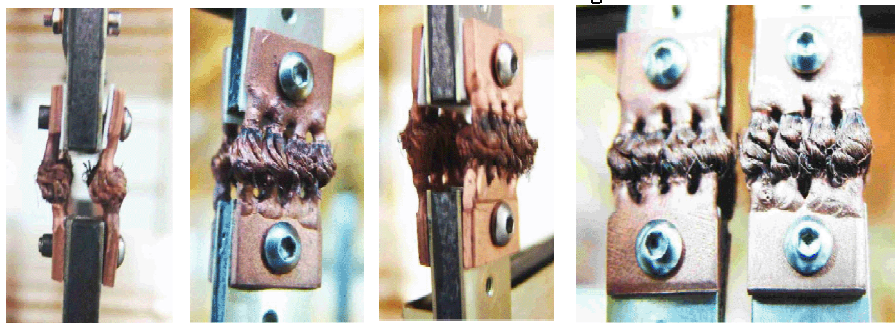
Thermal bars are connected by thermal connectors made of Copper braids welded to small plates. Both faces of one connector are shown below:



Compression along Z-axis is applied to the braids in order to restore flexibility and to adjust the length in Z. Pictures below show a connector after compression.



This compression was performed *in situ* during assembly of the 3 planes of the inner tracker but before the definitive connexion. Some braids were damaged:



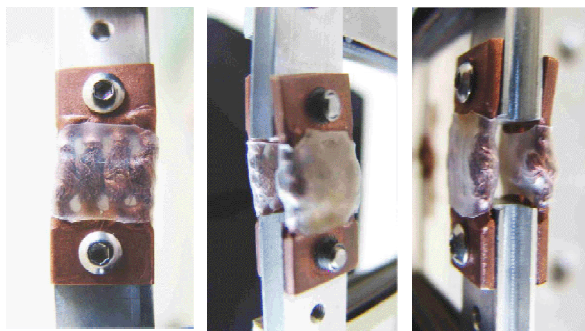
#### Remarks:

- Some weakness of the metal properties might have been introduced by the welding of the Copper braids
- The effect on thermal conductivity is negligible.
- The damaged threads showed a single break.
- No one was found to be loose.

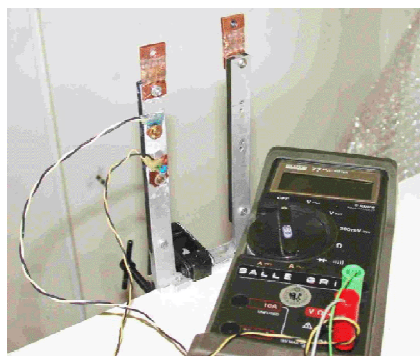
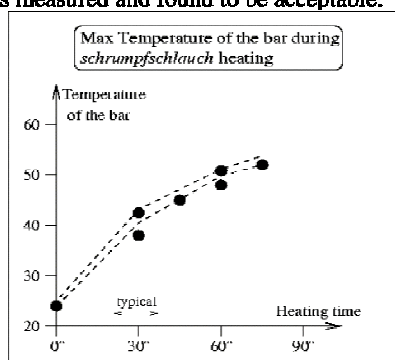


## **Appendix B: Containment of Copper braids**

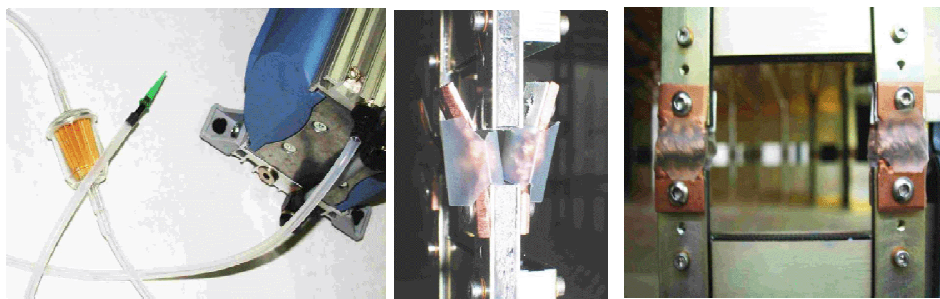
We studied the use of Kynar heat shrink tubing (space qualified) to enclose the Copper braids. Preliminary tests on prototypes are shown below:



The tube is heated during ~ 30 seconds. The effect on the temperature of electronic hybrid circuits was measured and found to be acceptable:



A procedure was established and was applied on all thermal connectors. A preliminary cleaning was made with a micro vacuum cleaner. The filter was examined. No broken thread was found in the filter.



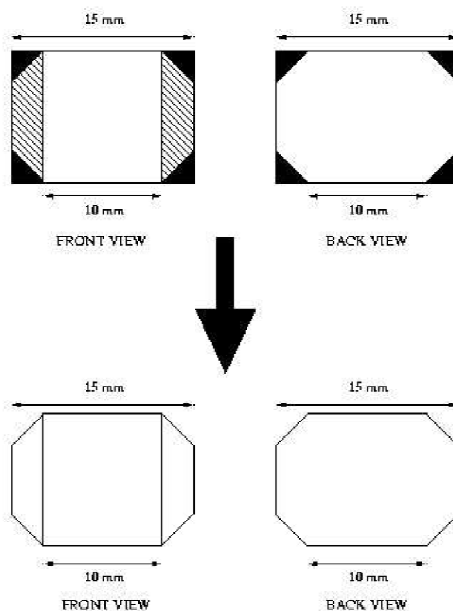


**Appendix C: Detailed implementation of procedure and controls****AMS-02 Tracker : Heat-Shrink Tube Installation**

Date : ... / ... / 200...	Time : .....	Done by : .....
Octant : .....	Column : .....	

**1- Preparation of the Samples**

	Ok	Comment
1. Take the Heat-Shrink Tube : diameter=21,1 mm (flattened).	<input type="checkbox"/>	.....
2. Cut 4 Samples of 15 mm length.	<input type="checkbox"/>	.....
3. Adjust the shape of the samples in accordance with the following pattern :	<input type="checkbox"/>	.....

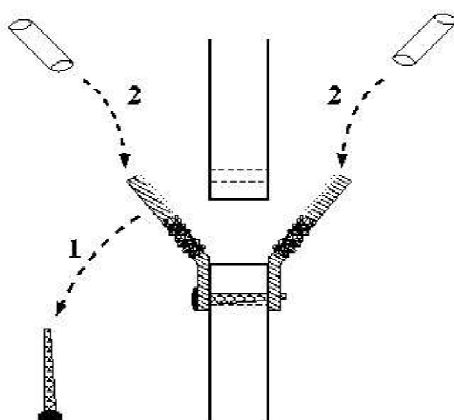


- |   |                          |       |
|---|--------------------------|-------|
| 4. Clean the samples (Isopropyl alcohol). | <input type="checkbox"/> | ..... |
|---|--------------------------|-------|



## 2- Installation

	Ok	Comment
1. Protect the corresponding plane with a 'PlexiBulle' cover.	<input type="checkbox"/>	.....
2. Find the location of the 4 copper connectors on the half-column.	<input type="checkbox"/>	.....
3. Rectify copper braids which exceed the width of the copper connectors.	<input type="checkbox"/>	.....
4. Unscrew the two pairs of copper connectors on the not-stuck side of the column.	<input type="checkbox"/>	.....
5. Clean the braids with the vacuum pump equipped with a filter.	<input type="checkbox"/>	.....
6. Check the filter.	<input type="checkbox"/>	.....
7. Put the heat-shrink tubes on each pairs (adjust the form if necessary).	<input type="checkbox"/>	.....



- |  |                          |       |
|--|--------------------------|-------|
| 8. Screw up the two pairs of connectors in order to maintain the tubes in the good position.   | <input type="checkbox"/> | ..... |
| 9. Use the 'micro-heater' (settings : 'heat'=3, 'blow'=5) to heat the heat-shrinkable tubes. Pay attention to the hot air direction (no hot air near the electronics boxes!) | <input type="checkbox"/> | ..... |
| 10. Check that the heat-shrinkable tubes cover well the braided part of the copper connectors.   | <input type="checkbox"/> | ..... |